Poe & Zimmerman

# A study of the properties of superheated steam

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# A STUDY OF THE PROPERTIES OF SUPERHEATED STEAM

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

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IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

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# A STUDY OF THE PROPERTIES OF SUPERHEATED STEAM.

## I. - INTRODUCTION

The advantage of superheated steam was known as early as 1828 when the Cornish engineers found it advantageous to keep the cylinder of a steam engine as hot as the steam that entered it. The cylinder was kept hot by surrounding it with fire-flues, and also by placing a fire underneath the cylinder. The French also investigated the use of superheated steam, but it was not until 1855 that the present system of superheating was developed by a German engineer, Hirn, and adapted to practical uses by Wethered, an American engineer. Although superheated steam had been more or less used in Europe at this time, practically nothing had been done in this country as late as 1896.

Much has been accomplished since 1896, in the development of the use of superheated steam. Its application has been slow, due, not to a lack of theoretical knowledge, but to mechanical difficulties such as - the burning of packing, destruction of lubricants, and excessive expansion of valves and cylinders. These difficulties, have been gradually overcome and at present superheated steam is being used to a great extent.

The growing use of superheated steam renders an exact knowledge of the properties of this medium desirable. Very reliable experimental data are at present available, and it seems possible to build up a connected theory from which the properties in question can be calculated without recourse to approximation.

Two theories have already been presented, but both have been proved defective in the light of the recent Munich experiments. Zeuner's theory which has been used to a great extent, was based

on the assumption of constant specific heat, an assumption now known to be incorrect. In a second theory proposed by Callendar, fundamental equations are derived from certain theoretical considerations. Although Callendar's theory gives results which do not agree with the decisive experimental results of Knoblanch, Linde and Klebe, the method employed by him is suggestive.

Without the aid of a theory, two tables of the properties of superheated steam have been constructed, that by Prof. Peabody and that by Prof. Marks and Dr. Davis. The numerical results were in both cases obtained by graphical integration with assumed specific heat curves with which to start. While the validity and the accuracy of this procedure cannot be questioned, it must be felt that much better methods should be found.

In an investigation by Prof. Goodenough, this want is supplied by the development of a complete working theory of the essential properties of superheated steam within the region of superheat ordinarily employed. Starting with a modified form of Linde's characteristic equation, general expressions are obtained for the specific heat at constant pressure, the heat content, the entropy and the intrinsic energy. The constants of these equations were determined by means of the most reliable experimental evidence at hand. The final result is a set of equations from which the properties just enumerated can be calculated directly without measurement or approximation.

## II. - DERIVATION OF FUNDAMENTAL EQUATIONS:

The following derivation of the equations used in this thesis was supplied by Prof. Goodenough.

CHARACTERISTIC EQUATION:

The accurate experiments of Knoblauch, Linde, and Klebe furnish reliable data for a characteristic equation connecting the pressure, temperature, and volume of superheated steam. To represent these experiments, Linde proposed in the first instance the equation

$$pv = BT - C\left(\frac{373}{T}\right)^2 - D\,\frac{1}{v} \qquad (1)$$

but for the sake of convenience in calculations, settled finally upon the equation

$$pv = BT - p(1 + ap)\,C\left(\frac{373}{T}\right)^3 - D \qquad (2)$$

Callendar proposed the equation

$$v - b = \frac{BT}{p} - C_0\left(\frac{273}{T}\right)^{3.5} \qquad (3)$$

If T is made a constant in equations (2) and (3) and the product pv is denoted by a single symbol, say y, the resulting forms are

$$y = C - C'p + C''p^2 \qquad (2')$$

$$y = C + C'p \qquad (3')$$

That is, the isothermal of superheated steam when drawn on a plane, having the product pv as ordinates and the pressure as abscissae, appear as parabolic curves when Linde's equation (2) is used and as straight lines when Callendar's equation is chosen. Experiments show the isothermals as curves rather than straight lines, and the curves may be represented fairly well by parabolas. Hence, we are forced to accept Linde's equation in preference to Callendar's, as Linde's is probably more representative of the facts.

There is one objection to the assumed form of the equation to which Linde himself calls attention, which lies in the fact that

at a temperature of about 402 deg. C the"correction term" of the second term changes sign and for higher temperatures, the fluid becomes a "more than perfect" gas. He suggests that this objection may be obviated by increasing the exponent from 3 to 3.5, which is the value assumed by Callerdar. However, the value 3 was retained for the sake of convenience in computation.

Let (2) be written in the equivalent form

$$pv = BT - p(1 + ap)\left(\frac{m}{T^n} - D\right)$$

where n replaces the integral value 3 as the exponent of T. Now it may be seen that the term $(m/T^n - D)$ for a constant value of T may be kept constant by decreasing n and at the same time increasing D, or vice versa, and a trial of different constants shows that by suitably choosing a, n, and D, n may be given quite different values between 3 and 4 and the resulting equation will represent the experiments with practically equal accuracy. By taking n=4, D was found to be negative; hence for some values of n between 3 and 4, D must become zero, and the characteristic equation will consequently take the following form

$$pv = BT - p(1 + ap)\frac{m}{T^n} \qquad (4)$$

By plotting corresponding values of n and D it was found that the constant D vanished when n = 3.5 almost exactly. Since the value 3.5 is convenient in calculations it is the one assumed. Knowing n, values of B, a, and m may be found that will make equation (4) represent satisfactorily the experimental results. Without changing the accuracy of the results to any great extent, the constant a can be varied considerably. Linde assumed a = 0.000002, but the value 0.000001 has proven to give better results. When n and a are assumed, the values B and m are practically fixed. The

values finally chosen were as follows:

| | | |
|---|---|---|
| Log m = 7.41320 | ) | Metric System |
| B = 47.06 | ) | |

| | | |
|---|---|---|
| Log m = 9.50308 | ) | |
| n = 3.5 | ) | English System. |
| B = 0.5956 | ) | where p is in lb. per sq. in. |
| a = 0.0007 | ) | |

| | | |
|---|---|---|
| B = 85.77 | ) | English System. |
| a = 0.0000049 | ) | where p is in lb. per sq. ft. |

FORMULA FOR SPECIFIC HEAT:

From the general principles of thermodynamics, we have the relation

$$\left(\frac{\partial C_p}{\partial p}\right)_{T=\text{constant}} = -AT\frac{\partial^2 v}{\partial T^2} \qquad (5)$$

which applies to all substances. Equation (4) may be written in the form

$$v = \frac{BT}{p} - (1 + ap)\frac{m}{T^n}$$

Differentiating

$$\frac{\partial v}{\partial T} = \frac{B}{p} + \frac{mn}{T^{n+1}}(1 + ap)$$

$$\frac{\partial^2 v}{\partial T^2} = -\left(\frac{mn(n+1)}{T^{n+2}}\right)(1 + ap)$$

whence for superheated steam (5) becomes

$$\left(\frac{\partial C_p}{\partial p}\right)_T = \frac{Amn(n+1)}{T^{n+1}}(1 + ap) \qquad (6)$$

Let T be a constant; then by integrating (6) we have

$$C_p = \frac{Amn(n+1)}{T^{n+1}}\, p(1 + \frac{a}{2}p) + \text{constant of integration}$$

The constant of integration may be a function of T, since T was held constant during the integration.

Hence

$$Cp = \phi(T) + \frac{Amn(n+1)}{T^{n+1}} p(1 + \frac{a}{2}p) \qquad (7)$$

or

$$Cp = \phi(T) + f(p,T) \qquad (7')$$

if the term

$$\frac{Amn(n+1)}{T^{n+1}} p(1 + \frac{a}{2}p)$$

is replaced for convenience by f(p,T)

If the characteristic equation (4) is correct the expression for the specific heat must have the form given by (7); and if the arbitrary function $\phi(T)$ can be determined we shall have an expression for $C_p$ in terms of the variables p and T.

Callendar and Linde have obtained equations similar to equation (7) by starting from their respective equations (3) and (2).

The determination of the proper form for the function $\phi(T)$ is the critical point of the whole investigation. If in (7), p = 0, the equation reduces to

$$C_p = \phi(T)$$

Callendar reasons that at zero pressure the specific $C_p$ should have an invariable value $(C_p)_o$ independent of the temperature; hence $\phi(T)$ is assumed to be constant. Linde follows Callendar in this assumption. Knoblanch and Jakob, however, on the strength of their direct experiments on the values of $C_p$, show that $(C_p)_o$ cannot be constant. A form of the function can be established by another line of reasoning. Inspection of (7) shows that the "correction term" f(p,T), having the factor $T^{n+1}$ in the denominator, grows smaller rapidly as T increases. At low temperatures (T = 400 deg. to 600 deg. C) this term has an appreciable value, but at temperatures above 1500 deg. C, the exponent n+1

being 4.5, the term practically disappears, and the specific heat is given by the simple relation

$$C_p = \phi(T)$$

for all pressures. The experiments of Mallard and Le Chatelier, at temperatures above 3000 deg. C and of Langen for temperatures around 1500 deg. C show that at these temperatures there is a linear relation between the specific heat and temperature; that is

$$Cp = \alpha + \beta T$$

As a first approximation, the form of the arbitrary function may be assumed to be

$$\phi(T) = \alpha + \beta T \qquad (8)$$

By a closer investigation, it may be shown that the function should be quadratic instead of linear, thus

$$\phi(T) = \alpha + \beta T + \gamma T^2 \qquad (9)$$

By the assumption of this form of $\phi(T)$, with the proper values of the constants, $\alpha$, $\beta$, and $\gamma$, the apparently conflicting experiments of Mallard and LeChatelier, Langen, Holborn and Henning, and Knoblanch and Jakob may be in a large degree reconciled. The addition of $\gamma T^2$, however, further complicates the equation that expresses the various properties of superheated steam and for the region relatively close to the saturation limit the simpler relation is preferable.

Taking the expression for $\phi(T)$ given by (8), the general expression for $C_p$ becomes

$$C_p = \alpha + \beta T + \frac{Amn(n+1)}{T^{n+1}} p(1 + \frac{a}{2}p) \qquad (10)$$

The following characteristics may be referred directly from the equation:

1. - It is evident that all curves plotted from equation (10) will have the staight line $\alpha + \beta T$ as an asymptote.

2. - For the same temperatures, the value of $C_p$ increases with the pressure; that is, the constant pressure curves are separated, and the higher the pressure, the farther the curves from the T-axis.

3. - Each curve has a minimum. To show this take the derivative $dC_p/dT$ and equate it to zero, thus

$$\frac{dC_p}{dT} = \beta - \frac{Amn(n+1)^2}{T^{n+2}} p(1 + \frac{a}{2}p)$$

This derivative takes the value zero when T takes the value $T_m$ given by the equation.

$$\beta T_m^{n+2} = Amn(n+1)^2 p(1 + \frac{a}{2}p)$$

The value of $C_p$ for this minimum is

$$(Cp)_m = \alpha + \frac{n+2}{n+1}\beta$$

4. - The value $T_m$ for which $C_p$ becomes a minimum, increases with the pressure; that is, the minimum points of the successive curves recede from the $C_p$ axis. From these considerations it appears that the constant pressure curves derived from equation (10) have the same general form as the well known experimental curves of Knoblanch and Jakob.

The determination of the constants $\alpha$ and $\beta$ involves an examination of the experimental evidence on specific heat at present available.

The earlier experiments of Holborn and Henning at atmospheric pressure were satisfactorily represented by the linear equation

$$C_p = 0.446(1 + 0.000192t)$$

or (11)

$$C_p = 0.446 + 0.0000956t)$$

The range of these experiments was 110 deg. C to 800 deg. C. The second set of experiments extending to 1400 deg. C showed, however, that the linear relation does not hold for the higher temperatures. The final equation deduced by Holborn and Henning for the mean specific heat between 100 deg. C and t deg. C is

$$c_{100,t} = 0.4669 - 0.0000168t + 0.000000044t^2$$

The corresponding equation giving the relation between the true specific heat and temperature is

$$C_p = 0.4686 - 0.000424t - 0.000000132t^2 \qquad (12)$$

The experiments of Langen (1300 deg. C to 1700 deg. C) are represented by the linear equation

$$C_p = 0.438 + 0.000239t \qquad (13)$$

Those by Mallard and LeChatelier at temperatures above 3000 deg. C by the equation

$$C_p = 0.432 + 0.000318t \qquad (14)$$

Comparing equations (11), (13) and (14), it appears that the coefficient is larger the higher the temperature at which the experiments were made. Evidently, however, the limits for $\beta$ are set by the coefficient 0.0000956 of (11) and the coefficient 0.000318 of (14). The discrepancy between these coefficients has led Knoblanch and Jakob to suggest that the relation between $C_p$ and t is not linear but should be represented by a curve of parabolic form. This means that the function $\phi(T)$ of (7) should have the form

$$\phi(T) = \alpha + \beta T + \gamma T^2$$

which is probably true if equation (7) is to hold for the entire superheated region. However, since we restrict the region under consideration to temperatures below 800 deg. or 900 deg. C, we are

justified in taking the linear relation

$$\phi(T) = \alpha + \beta T,$$

provided $\beta$ is so chosen as to give the line a slope that will approximate the mean slope of the curve throughout the region. A few trials showed that the value of $\beta = 0.00018$ gave results consistent with Knoblanch and Jakob's experiments, and the following relations were finally adopted. For the centigrade scale and absolute temperatures

$$\phi(T) = 0.372 + 0.00018T.$$

For ordinary temperatures (Centigrade)

$$\phi(t) = 0.4212 + 0.00018t$$

For the Fahrenheit scale

$$\left.\begin{aligned}\phi(T) &= 0.372 + 0.0001T\\ \phi(t) &= 0.418 + 0.0001t\end{aligned}\right\} \qquad (15)$$

In the determination of $\alpha$ and $\beta$ the experiments of Knoblanch and Jakob were given the greatest weight. A comparison of the constant pressure curves calculated from (10) agreed very satisfactorily with the experiments just mentioned; in fact at the two lower pressures it is quite remarkable, while at a pressure of 8 Kg., the difference between the curve and the experimental points is not greater than the difference between the points themselves.

Since formula (10) and the curves derived from it are all important in subsequent analysis, it is necessary to make a critical comparison between these curves and the $C_p$ curves that have heretofore been employed. Knoblanch and Jakob deduced from their experiments a set of curves that have been regarded as authoritative. Their curves for 6 and 8 Kg. have a sharper slope towards the saturation limit than the calculated curves, and they also rise with a

greater slope after passing through the minimum value. On the strength of Holborn and Henning's experiments, Prof. Heck has questioned the slope of the Knoblanch curves at the higher temperatures, Marks and Davis have used the Knoblanch curves modified in two particulars. The curve for atmospheric pressure is lowered at the higher temperatures to join with Holborn and Henning's curves, and the other curves are lowered to correspond. Near the saturation the values of $C_p$ were somewhat increased for the lower pressures. As a result, the $C_p$ curves employed by Marks and Davis are nearly horizontal at about 800 deg. to 900 deg. F.

Two questions, therefore, demand close consideration. First, at the higher temperatures should the values of $C_p$ rise sharply with the temperature, as indicated by the empirical curves of Knoblanch and Jakob, or should the rate increase be relatively small as assumed by Marks and Davis? According to the extrapolated curves given by Knoblanch and Jakob and followed by Marks and Davis the values of $C_p$ at saturation attain very high values at the higher pressures; thus at pressures of 300 pounds $C_p$=0.89; at 350 pounds $C_p$ = 1.01.

Various $C_p$ curves have been plotted for temperature intervals 100 deg. to 450 deg. C, all being based on a pressure of one atmosphere. Holborn and Henning's first relation is given by a straight line, equation (11) and their second relation by equation (12). Langen's formula is represented by equation (13). It was noted that the slope of the Knoblanch and Jakob curves, for temperatures above 3000 deg., was too great. This curve, if extended, would cross Langen's curve at about 500 deg., and at a temperature of 1500 deg. would give a value of $C_p$ greatly in excess of that found by Langen. Furthermore, there is really no jus-

tification for this slope in the experimental results. The Knoblanch and Jakob curves were arbitrarily made to fit the experimental points as closely as possible, regardless of the fact that those points must necessarily deviate somewhat from the exact values. It is apparent from the curves that were plotted that the curve calculated from (10) represented the experiments at the two lower pressures fully as well as the empirical curves with their greater slopes. Turning to the Holborn and Henning curves it was noted that the slope of the curves were smaller than the curve calculated from (10). As was previously stated, Marks and Davis modified the Knoblanch and Jakob curves so as to give them slopes corresponding to Holborn and Henning's curves calculated from the first relation, equation (11). Holborn and Henning observe in their discussion of their results that there is a discrepancy of about 12 percent between their values of $C_p$ and Langen's values at 1400 deg. to 1600 deg. C; and Callendar suggests that Holborn and Henning's method is subject to systematic errors that make the results small by as much as 10 percent at the higher temperatures. There is no possibility of reconciling the experimental results of Holborn and Henning with those of Knoblanch and Jakob; and we are bound to give preference to the direct method of the later experimenters. It is, therefore, fair to conclude that Holborn and Henning's curves show too small a rise with tho temperature, and the curve calculated from equation (10), which agrees fairly well with the Knoblanch and Jakob experiments, represents very nearly within the temperature range 100 deg. to 600 deg. C the true course of the $C_p$ curves.

From the preceding discussion, it appears probable that the

proposed formula (10) may be accepted as giving with considerable accuracy the specific heat $C_p$ of superheated steam between the saturation limit and about 1200 deg. F, which is the range of the ordinary technical application of the fluid. To give accurate values of temperatures above 1200 deg. the equation must be modified by the addition of a term $\gamma T^2$ with appreciable change of constants.

HEAT CONTENT, ENERGY, AND ENTROPY:

With the aid of an explicit formula for the specific heat, expressions for the heat contents, energy, and entropy, may be derived. For this purpose, the general equation

$$dq = C_p dT - AT\left(\frac{\partial v}{\partial T}\right)_p dp \qquad (16)$$

is most convenient. Since the heat content i is defined by the relation

$$i = A(u + pv)$$

we have

$$di = dq + Avdp$$

whence from (16)

$$di = C_p dT - A\left(T\frac{\partial v}{\partial T} - v\right)dp \qquad (17)$$

From the characteristic equation (4) the derivative $\partial v/\partial T$ is found to be

$$\frac{\partial v}{\partial T} = \frac{B}{p} + \frac{nm}{T^{n+1}}(1 + ap)$$

Substituting this and also the expression for $C_p$ in (17), the result is

$$di = (\alpha + \beta T)dT + Anm(n+1)p\left(1 + \frac{a}{2}p\right)\frac{dT}{T^{n+1}} - \frac{Am(n+1)}{T^n}(1+ap)dp$$

The integral of this exact differential is readily found to be

$$i = \alpha T + \frac{1}{2}\beta T^2 - \frac{Am(n+1)}{T^n} p(1 + \frac{a}{2}p) + i_o \qquad (18)$$

Since $Au = i - Apv$, we obtain for the energy expressed in thermal units

$$Au = T(\alpha + \frac{1}{2}\beta T - AB) - \frac{Amp}{T^n}\left[n + (n-1)\frac{a}{2}p\right] + i_o \qquad (19)$$

For the entropy an expression is readily found from (16), thus

$$ds = \frac{dq}{T} = C_p(\frac{dT}{T}) - A(\frac{\partial v}{\partial T})\ dp$$

Introducing in this equation the expressions previously derived for $C_p$ and $\partial v/\partial T$, the result is

$$ds = (\frac{\alpha}{T} - \beta)dT + Amn(n+1)p(1 + \frac{a}{2}p)\frac{dT}{T^{n+2}} - AB\frac{dp}{p} - \frac{Amn}{T^{n+1}}(1-ap)dp$$

The integral is

$$s = \alpha \log_e T - \beta T - AB\operatorname{Log}_e p - Anp(1 + \frac{a}{2}p)\frac{m}{T^{n+1}} + s_o \qquad (20)$$

The constants of integration $i_o$ and $s_o$ may be obtained by passing to the saturation limit. Thus let (18) be written $i = i' + i_o$, where $i'$ stands for the variable part of the second member. The constants $\alpha$, $\beta$, m, n, and a being known, $i'$ can be found for any assumed pressure p, and the corresponding saturation temperature T; from the properties of saturated steam i is known for this same state, and $i_o$ is at once determined by subtraction. In the same way, $s_o$ may be determined.

## III - OBJECT OF THESIS:

The purpose of this thesis is:

1. - To calculate Superheated Steam Tables based on the equation for volume, total heat, and entropy, as derived above.
2. - To construct a chart, by means of which for a given p and T, the properties may be read off directly.

## IV - METHOD OF CALCULATION:

It was observed that p and T were the variables in each

case; that is, for any T and p in the superheat region, v, i, and s could be calculated directly without recourse to approximation. Marks and Davis take the temperature above saturation, that is superheat, but for our purpose it seemed better to take T directly. The value T was varied from 590 deg. to 1200 deg. F by 10 deg. intervals to 1000 deg., and then by intervals of 50 deg. Pressures were taken from 1 pound to 300 pounds by various intervals, those near zero were taken by one pound intervals, and the higher the pressure the greater the interval. By looking at the formulae it may be seen that some terms depend on T alone, some on p alone, and some on both T and p. These were all calculated separately and the results arranged in a double table, so that for any pressure and temperature the value of an element of any equation could be read off directly. Having calculated these elements the desired results were obtained by combining the elements according to the foregoing equations.

V. - RESULTS:

The results obtained are shown by the tables contained in the following pages - 16 to 38.

VI. - CONSTRUCTION OF CHART:

The results as given in the tables are plotted graphically as shown by diagram I. In this diagram, heat contents were used as ordinates and entropy as abscissae, giving lines of constant pressures and constant temperatures. Points on the constant pressure curves were obtained by plotting the values of heat contents and the corresponding values of entropy, for the series of constant pressures. In the same way constant temperature curves were obtained by plotting the values of heat contents and the corresponding values for the series of constant temperatures.

TABLE I.

SUPERHEATED STEAM.

Volumes in English Units.

| Pressure lb. per sq. in. | Absolute Temperatures - Fahrenheit Scale. 590 | 600 | 610 | 620 | 630 | 640 | 650 | 660 |
|---|---|---|---|---|---|---|---|---|
| 1 | 350.76 | 356.86 | 362.75 | 368.72 | 374.72 | 380.70 | 386.68 | 392.66 |
| 2 | | 178.08 | 180.99 | 184.09 | 187.11 | 190.11 | 193.11 | 196.02 |
| 3 | | 118.52 | 120.54 | 122.54 | 124.57 | 126.58 | 128.59 | 130.60 |
| 4 | | | | 91.77 | 93.30 | 94.81 | 96.33 | 97.84 |
| 5 | | | | | 74.54 | 75.75 | 76.97 | 78.19 |
| 6 | | | | | 62.03 | 63.05 | 64.07 | 65.08 |
| 7 | | | | | | 53.97 | 54.85 | 55.72 |
| 8 | | | | | | | 48.83 | 49.70 |
| 9 | | | | | | | 42.46 | 43.24 |
| 10 | | | | | | | | 38.87 |
| 11 | | | | | | | | 35.30 |
| 12 | | | | | | | | |
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| 62 | | | | | | | | |
| 64 | | | | | | | | |
| 66 | | | | | | | | |
| 68 | | | | | | | | |
| 70 | | | | | | | | |

| Pressure lb. per sq. in. | 670 | 680 | 690 | 700 | 710 | 720 | 730 | 740 |
|---|---|---|---|---|---|---|---|---|
| 1 | 398.64 | | | | | | | |
| 2 | 199.12 | 202.11 | | | | | | |
| 3 | 132.61 | 134.61 | 136.62 | | | | | |
| 4 | 99.35 | 100.86 | 102.37 | 103.88 | | | | |
| 5 | 79.43 | 80.65 | 81.87 | 83.09 | | | | |
| 6 | 66.10 | 67.11 | 68.12 | 69.13 | | | | |
| 7 | 56.60 | 57.50 | 58.34 | 59.20 | 60.07 | | | |
| 8 | 49.40 | 50.23 | 51.00 | 51.76 | 52.42 | 53.28 | | |
| 9 | 43.93 | 44.61 | 45.29 | 45.97 | 46.65 | 47.21 | 48.00 | |
| 10 | 39.49 | 40.11 | 40.72 | 41.23 | 41.95 | 42.56 | 43.17 | 43.78 |
| 11 | 35.86 | 36.43 | 36.99 | 37.55 | 38.11 | 38.66 | 39.22 | 39.48 |
| 12 | 32.84 | 33.34 | 33.87 | 34.39 | 34.90 | 35.41 | 35.93 | 36.44 |
| 13 | 30.28 | 30.76 | 31.24 | 31.72 | 32.20 | 32.67 | 33.14 | 33.61 |
| 14 | | 28.53 | 28.98 | 29.42 | 29.87 | 30.31 | 30.75 | 31.19 |
| 15 | | 26.61 | 27.02 | 27.44 | 27.85 | 28.27 | 28.68 | 29.19 |
| 16 | | 24.92 | 25.31 | 25.70 | 26.09 | 26.48 | 26.87 | 27.25 |
| 17 | | | 23.80 | 24.17 | 24.54 | 24.90 | 25.27 | 25.63 |
| 18 | | | 22.46 | 22.81 | 23.15 | 23.50 | 23.85 | 24.19 |
| 19 | | | ——— | 21.59 | 21.92 | 22.25 | 22.58 | 22.90 |
| 20 | | | 20.17 | 20.49 | 20.80 | 21.12 | 21.43 | 21.78 |
| 22 | | | 18.30 | 18.59 | 18.88 | 19.17 | 19.45 | 19.74 |
| 24 | | | 16.75 | 17.01 | 17.28 | 17.54 | 17.81 | 18.07 |
| 26 | | | | 15.68 | 15.92 | 16.17 | 16.41 | 16.66 |
| 28 | | | | | 14.76 | 14.99 | 15.32 | 15.45 |
| 30 | | | | | 13.75 | 13.97 | 14.18 | 14.40 |
| 32 | | | | | | 13.08 | 13.28 | 13.48 |
| 34 | | | | | | 12.29 | 12.48 | 12.67 |
| 36 | | | | | | 11.59 | 11.77 | 11.95 |
| 38 | | | | | | 10.86 | 11.13 | 11.30 |
| 40 | | | | | | | 10.56 | 10.72 |
| 42 | | | | | | | 10.04 | 10.20 |
| 44 | | | | | | | 9.57 | 9.72 |
| 46 | | | | | | | 9.14 | 9.28 |
| 48 | | | | | | | | 8.88 |
| 50 | | | | | | | | |
| 52 | | | | | | | | |
| 54 | | | | | | | | |
| 56 | | | | | | | | |
| 58 | | | | | | | | |
| 60 | | | | | | | | |
| 62 | | | | | | | | |
| 64 | | | | | | | | |
| 66 | | | | | | | | |
| 68 | | | | | | | | |
| 70 | | | | | | | | |

| Pressure lb. per sq. in. | 750 | 760 | 770 | 780 | 790 | 800 | 810 | 820 |
|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
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| 7 | | | | | | | | |
| 8 | | | | | | | | |
| 9 | | | | | | | | |
| 10 | | | | | | | | |
| 11 | | | | | | | | |
| 12 | 36.95 | | | | | | | |
| 13 | 34.08 | 34.55 | 35.02 | | | | | |
| 14 | 31.67 | 32.07 | 32.50 | 32.94 | 33.38 | | | |
| 15 | 29.50 | 29.91 | 30.32 | 30.72 | 31.14 | 31.54 | 31.95 | |
| 16 | 27.64 | 28.02 | 28.41 | 28.79 | 29.17 | 29.56 | 29.94 | 30.32 |
| 17 | 26.00 | 26.36 | 26.72 | 27.08 | 27.44 | 27.80 | 28.16 | 28.52 |
| 18 | 24.54 | 24.88 | 25.22 | 25.57 | 25.91 | 26.25 | 26.59 | 26.93 |
| 19 | 23.23 | 23.56 | 23.88 | 24.21 | 24.53 | 24.85 | 25.18 | 25.50 |
| 20 | 22.05 | 22.36 | 22.67 | 22.98 | 23.29 | 23.60 | 23.91 | 24.21 |
| 22 | 20.02 | 20.31 | 20.59 | 20.87 | 21.15 | 21.43 | 21.71 | 21.99 |
| 24 | 18.33 | 18.58 | 18.85 | 19.11 | 19.36 | 19.53 | 19.89 | 20.14 |
| 26 | 16.90 | 17.14 | 17.38 | 17.62 | 17.86 | 18.10 | 18.34 | 18.58 |
| 28 | 15.67 | 15.90 | 16.12 | 16.25 | 16.57 | 16.79 | 17.01 | 17.24 |
| 30 | 14.61 | 14.81 | 15.03 | 15.24 | 15.45 | 15.66 | 15.77 | 16.07 |
| 32 | 13.67 | 13.88 | 14.07 | 14.27 | 14.47 | 14.66 | 14.86 | 15.06 |
| 34 | 12.86 | 13.04 | 13.23 | 13.42 | 13.60 | 13.79 | 13.97 | 14.16 |
| 36 | 12.13 | 12.30 | 12.48 | 12.66 | 12.83 | 13.01 | 13.18 | 13.36 |
| 38 | 11.47 | 11.63 | 11.81 | 11.98 | 12.15 | 12.31 | 12.48 | 12.64 |
| 40 | 10.87 | 11.05 | 11.21 | 11.37 | 11.53 | 11.67 | 11.85 | 12.00 |
| 42 | 10.35 | 10.51 | 10.66 | 10.81 | 10.97 | 11.12 | 11.27 | 11.42 |
| 44 | 9.87 | 10.02 | 10.16 | 10.31 | 10.46 | 10.60 | 10.76 | 10.89 |
| 46 | 9.43 | 9.57 | 9.71 | 9.85 | 10.00 | 10.13 | 10.27 | 10.41 |
| 48 | 9.02 | 9.16 | 9.29 | 9.43 | 9.56 | 9.70 | 9.83 | 9.96 |
| 50 | 8.65 | 8.78 | 8.91 | 9.04 | 9.17 | 9.30 | 9.43 | 9.56 |
| 52 | 8.30 | 8.43 | 8.56 | 8.68 | 8.81 | 8.93 | 8.96 | 9.18 |
| 54 | 7.99 | 8.11 | 8.23 | 8.35 | 8.47 | 8.59 | 8.71 | 8.83 |
| 56 | 7.69 | 7.81 | 7.93 | 8.04 | 8.16 | 8.28 | 8.39 | 8.51 |
| 58 | 7.41 | 7.53 | 7.64 | 7.76 | 7.87 | 7.99 | 8.10 | 8.21 |
| 60 | | 7.27 | 7.38 | 7.49 | 7.60 | 7.71 | 7.82 | 7.93 |
| 62 | | 7.02 | 7.13 | 7.24 | 7.35 | 7.46 | 7.56 | 7.67 |
| 64 | | 6.80 | 6.90 | 7.21 | 7.11 | 7.21 | 7.32 | 7.42 |
| 66 | | 6.58 | 6.69 | 6.79 | 6.89 | 6.99 | 7.09 | 7.19 |
| 68 | | 6.38 | 6.48 | 6.58 | 6.68 | 6.78 | 6.87 | 6.97 |
| 70 | | | 6.29 | 6.38 | 6.48 | 6.58 | 6.67 | 6.76 |

| Pressure lb. per sq. in. | 830 | 840 | 850 | 860 | 870 | 880 | 890 | 900 |
|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | |
| 2 | | | | | | | | |
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| 13 | | | | | | | | |
| 14 | | | | | | | | |
| 15 | | | | | | | | |
| 16 | | | | | | | | |
| 17 | 28.88 | | | | | | | |
| 18 | 27.27 | 27.61 | | | | | | |
| 19 | 25.82 | 26.14 | 26.46 | | | | | |
| 20 | 24.52 | 24.83 | 25.13 | 25.44 | | | | |
| 22 | 22.27 | 22.55 | 22.83 | 23.10 | 23.39 | 23.66 | | |
| 24 | 20.40 | 20.66 | 20.81 | 21.16 | 21.42 | 21.68 | 21.83 | |
| 26 | 18.82 | 19.05 | 19.29 | 19.52 | 19.76 | 19.98 | 20.23 | 20.47 |
| 28 | 17.46 | 17.70 | 17.90 | 18.12 | 18.34 | 18.56 | 18.78 | 19.00 |
| 30 | 16.28 | 16.49 | 16.69 | 16.90 | 17.10 | 17.31 | 17.51 | 17.72 |
| 32 | 15.25 | 15.54 | 15.64 | 15.83 | 16.00 | 16.22 | 16.41 | 16.60 |
| 34 | 14.34 | 14.52 | 14.71 | 14.88 | 15.07 | 15.35 | 15.43 | 15.62 |
| 36 | 13.53 | 13.71 | 13.98 | 14.05 | 14.23 | 14.40 | 14.57 | 14.74 |
| 38 | 12.80 | 12.98 | 13.14 | 13.30 | 13.46 | 13.63 | 13.79 | 13.96 |
| 40 | 12.16 | 12.32 | 12.47 | 12.63 | 12.79 | 12.94 | 13.10 | 13.25 |
| 42 | 11.57 | 11.72 | 11.87 | 12.02 | 12.17 | 12.32 | 12.46 | 12.58 |
| 44 | 11.04 | 11.18 | 11.32 | 11.46 | 11.61 | 11.75 | 11.89 | 12.03 |
| 46 | 10.56 | 10.68 | 10.82 | 10.96 | 11.10 | 11.23 | 11.37 | 11.50 |
| 48 | 10.09 | 10.23 | 10.36 | 10.49 | 10.62 | 10.76 | 10.89 | 11.02 |
| 50 | 9.69 | 9.80 | 9.94 | 10.07 | 10.19 | 10.31 | 10.44 | 10.57 |
| 52 | 9.30 | 9.43 | 9.55 | 9.67 | 9.79 | 9.81 | 10.03 | 10.15 |
| 54 | 8.95 | 9.07 | 9.19 | 9.30 | 9.42 | 9.54 | 9.63 | 9.77 |
| 56 | 8.63 | 8.74 | 8.86 | 8.96 | 9.08 | 9.19 | 9.30 | 9.42 |
| 58 | 8.32 | 8.43 | 8.54 | 8.65 | 8.76 | 8.87 | 8.98 | 9.09 |
| 60 | 8.04 | 8.14 | 8.25 | 8.36 | 8.46 | 8.57 | 8.68 | 8.76 |
| 62 | 7.77 | 7.88 | 7.98 | 8.08 | 8.19 | 8.29 | 8.49 | 8.49 |
| 64 | 7.52 | 7.62 | 7.72 | 7.82 | 7.92 | 8.02 | 8.12 | 8.22 |
| 66 | 7.29 | 7.40 | 7.48 | 7.58 | 7.68 | 7.78 | 7.87 | 7.97 |
| 68 | 7.07 | 7.16 | 7.26 | 7.35 | 7.45 | 7.54 | 7.64 | 7.73 |
| 70 | 6.86 | 6.95 | 7.05 | 7.14 | 7.23 | 7.32 | 7.41 | 7.50 |

| Pressure lb. per sq. in. | 910 | 920 | 930 | 940 | 950 | 960 | 970 | 980 |
|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | |
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| 19 | | | | | | | | |
| 20 | | | | | | | | |
| 22 | | | | | | | | |
| 24 | | | | | | | | |
| 26 | 20.70 | | | | | | | |
| 28 | 19.21 | 19.43 | | | | | | |
| 30 | 17.92 | 18.13 | 18.33 | 18.53 | | | | |
| 32 | 16.79 | 16.99 | 17.17 | 17.36 | 17.56 | | | |
| 34 | 15.80 | 15.98 | 16.16 | 16.34 | 16.52 | 16.70 | 16.88 | |
| 36 | 14.91 | 15.08 | 15.25 | 15.42 | 15.59 | 15.76 | 15.93 | 16.10 |
| 38 | 14.12 | 14.28 | 14.44 | 14.60 | 14.77 | 14.93 | 15.09 | 15.25 |
| 40 | 13.41 | 13.56 | 13.71 | 13.87 | 14.02 | 14.17 | 14.33 | 14.48 |
| 42 | 12.76 | 12.91 | 12.95 | 13.20 | 13.35 | 13.49 | 13.64 | 13.78 |
| 44 | 12.16 | 12.31 | 12.45 | 12.59 | 12.73 | 12.60 | 13.01 | 13.45 |
| 46 | 11.64 | 11.77 | 11.90 | 12.04 | 12.17 | 12.31 | 12.44 | 12.57 |
| 48 | 11.15 | 11.28 | 11.40 | 11.53 | 11.66 | 11.79 | 11.92 | 12.04 |
| 50 | 10.69 | 10.81 | 10.94 | 11.06 | 11.19 | 11.31 | 11.43 | 11.56 |
| 52 | 10.27 | 10.39 | 10.51 | 10.63 | 10.75 | 10.87 | 10.99 | 11.11 |
| 54 | 9.89 | 10.00 | 10.12 | 10.23 | 10.35 | 10.46 | 10.58 | 10.69 |
| 56 | 9.53 | 9.64 | 9.75 | 9.86 | 9.97 | 10.08 | 10.20 | 10.31 |
| 58 | 9.20 | 9.31 | 9.41 | 9.52 | 9.63 | 9.74 | 9.84 | 9.95 |
| 60 | 8.89 | 8.99 | 9.10 | 9.20 | 9.30 | 9.41 | 9.51 | 9.62 |
| 62 | 8.60 | 8.70 | 8.80 | 8.90 | 9.00 | 9.10 | 9.20 | 9.30 |
| 64 | 8.32 | 8.42 | 8.52 | 8.62 | 8.71 | 8.81 | 8.91 | 9.01 |
| 66 | 8.06 | 8.16 | 8.26 | 8.35 | 8.45 | 8.54 | 8.64 | 8.73 |
| 68 | 7.82 | 7.92 | 8.01 | 8.10 | 8.19 | 8.29 | 8.38 | 8.47 |
| 70 | 7.60 | 7.69 | 7.78 | 7.87 | 7.96 | 8.05 | 8.14 | 8.22 |

| Pressure lb. per sq. in. | 990 | 1000 | 1050 | 1100 | 1150 | 1200 |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
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| 24 | | | | | | |
| 26 | | | | | | |
| 28 | | | | | | |
| 30 | | | | | | |
| 32 | | | | | | |
| 34 | | | | | | |
| 36 | 16.27 | | | | | |
| 38 | 15.41 | 15.57 | | | | |
| 40 | 14.63 | 14.79 | | | | |
| 42 | 13.92 | 14.06 | | | | |
| 44 | 13.29 | 13.43 | | | | |
| 46 | 12.71 | 12.84 | | | | |
| 48 | 12.17 | 12.30 | 12.92 | | | |
| 50 | 11.68 | 11.80 | 12.42 | | | |
| 52 | 11.23 | 11.34 | 11.94 | | | |
| 54 | 10.81 | 10.92 | 11.49 | | | |
| 56 | 10.42 | 10.52 | 11.08 | 11.62 | | |
| 58 | 10.06 | 10.16 | 10.69 | 11.22 | 11.74 | 12.27 |
| 60 | 9.72 | 9.82 | 10.33 | 10.84 | 11.35 | 11.86 |
| 62 | 9.40 | 9.50 | 10.00 | 10.49 | 10.98 | 11.47 |
| 64 | 9.10 | 9.20 | 9.68 | 10.16 | 10.64 | 11.11 |
| 66 | 8.82 | 8.92 | 9.39 | 9.85 | 10.31 | 10.77 |
| 68 | 8.56 | 8.65 | 9.11 | 9.55 | 10.01 | 10.45 |
| 70 | 8.31 | 8.40 | 8.85 | 9.28 | 9.72 | 10.15 |

| Pressure lb. per sq. in. | 770 | 780 | 790 | 800 | 810 | 820 | 830 | 840 |
|---|---|---|---|---|---|---|---|---|
| 72 | 6.10 | 6.20 | 6.29 | 6.39 | 6.48 | 6.57 | 6.66 | 6.75 |
| 74 | 5.93 | 6.02 | 6.12 | 6.21 | 6.30 | 6.39 | 6.48 | 6.57 |
| 76 | 5.77 | 5.86 | 5.95 | 6.04 | 6.13 | 6.21 | 6.30 | 6.39 |
| 78 | 5.61 | 5.70 | 5.79 | 5.88 | 5.96 | 6.05 | 6.13 | 6.22 |
| 80 | | 5.56 | 5.64 | 5.72 | 5.81 | 5.89 | 5.97 | 6.06 |
| 82 | | 5.41 | 5.49 | 5.58 | 5.66 | 5.74 | 5.82 | 5.90 |
| 84 | | 5.28 | 5.36 | 5.44 | 5.52 | 5.60 | 5.68 | 5.76 |
| 86 | | 5.15 | 5.23 | 5.31 | 5.39 | 5.46 | 5.54 | 5.62 |
| 88 | | 5.02 | 5.10 | 5.18 | 5.26 | 5.34 | 5.41 | 5.49 |
| 90 | | 4.91 | 4.98 | 5.06 | 5.14 | 5.21 | 5.29 | 5.36 |
| 92 | | 4.79 | 4.88 | 4.94 | 5.02 | 5.09 | 5.17 | 5.24 |
| 94 | | | 4.76 | 4.83 | 4.91 | 4.98 | 5.05 | 5.12 |
| 96 | | | 4.66 | 4.73 | 4.80 | 4.87 | 4.94 | 5.01 |
| 98 | | | 4.56 | 4.63 | 4.70 | 4.77 | 4.84 | 4.91 |
| 100 | | | 4.46 | 4.53 | 4.60 | 4.67 | 4.74 | 4.80 |
| 105 | | | 4.23 | 4.30 | 4.37 | 4.43 | 4.50 | 4.57 |
| 110 | | | | 4.09 | 4.16 | 4.22 | 4.29 | 4.35 |
| 115 | | | | 3.91 | 3.97 | 4.03 | 4.09 | 4.15 |
| 120 | | | | | 3.79 | 3.85 | 3.91 | 3.97 |
| 125 | | | | | 3.63 | 3.69 | 3.74 | 3.80 |
| 130 | | | | | 3.48 | 3.54 | 3.59 | 3.65 |
| 135 | | | | | 3.34 | 3.40 | 3.45 | 3.50 |
| 140 | | | | | | 3.27 | 3.32 | 3.37 |
| 145 | | | | | | 3.15 | 3.20 | 3.25 |
| 150 | | | | | | 3.03 | 3.08 | 3.13 |
| 155 | | | | | | 2.93 | 2.97 | 3.02 |
| 160 | | | | | | | 2.88 | 2.92 |
| 165 | | | | | | | 2.78 | 2.82 |
| 170 | | | | | | | 2.70 | 2.74 |
| 175 | | | | | | | 2.61 | 2.65 |
| 180 | | | | | | | | |
| 185 | | | | | | | | |
| 190 | | | | | | | | |
| 195 | | | | | | | | |
| 200 | | | | | | | | |
| 210 | | | | | | | | |
| 220 | | | | | | | | |
| 230 | | | | | | | | |
| 240 | | | | | | | | |
| 250 | | | | | | | | |
| 260 | | | | | | | | |
| 270 | | | | | | | | |
| 280 | | | | | | | | |
| 290 | | | | | | | | |
| 300 | | | | | | | | |

| Pressure lb. per sq. in. | 850 | 860 | 870 | 880 | 890 | 900 | 910 | 920 |
|---|---|---|---|---|---|---|---|---|
| 72 | 6.84 | 6.93 | 7.02 | 7.11 | 7.20 | 7.29 | 7.38 | 7.47 |
| 74 | 6.65 | 6.74 | 6.83 | 6.92 | 7.00 | 7.09 | 7.18 | 7.26 |
| 76 | 6.47 | 6.56 | 6.64 | 6.73 | 6.81 | 6.90 | 6.98 | 7.07 |
| 78 | 6.30 | 6.39 | 6.47 | 6.55 | 6.64 | 6.72 | 6.80 | 6.88 |
| 80 | 6.14 | 6.22 | 6.30 | 6.38 | 6.47 | 6.55 | 6.63 | 6.71 |
| 82 | 5.99 | 6.07 | 6.15 | 6.22 | 6.30 | 6.38 | 6.46 | 6.54 |
| 84 | 5.84 | 5.92 | 5.94 | 6.07 | 6.15 | 6.23 | 6.30 | 6.38 |
| 86 | 5.70 | 5.77 | 5.85 | 5.93 | 6.00 | 6.08 | 6.16 | 6.23 |
| 88 | 5.56 | 5.64 | 5.71 | 5.79 | 5.86 | 5.94 | 6.01 | 6.08 |
| 90 | 5.44 | 5.51 | 5.58 | 5.66 | 5.73 | 5.80 | 5.87 | 5.94 |
| 92 | 5.31 | 5.39 | 5.46 | 5.53 | 5.60 | 5.67 | 5.75 | 5.81 |
| 94 | 5.20 | 5.27 | 5.34 | 5.41 | 5.48 | 5.55 | 5.62 | 5.69 |
| 96 | 5.08 | 5.15 | 5.22 | 5.29 | 5.36 | 5.43 | 5.50 | 5.56 |
| 98 | 4.98 | 5.04 | 5.11 | 5.18 | 5.25 | 5.31 | 5.38 | 5.45 |
| 100 | 4.87 | 4.94 | 5.01 | 5.07 | 5.14 | 5.20 | 5.27 | 5.33 |
| 105 | 4.63 | 4.69 | 4.76 | 4.82 | 4.89 | 4.95 | 5.01 | 5.07 |
| 110 | 4.41 | 4.47 | 4.53 | 4.59 | 4.66 | 4.72 | 4.78 | 4.84 |
| 115 | 4.21 | 4.27 | 4.33 | 4.39 | 4.45 | 4.50 | 4.56 | 4.62 |
| 120 | 4.03 | 4.08 | 4.14 | 4.20 | 4.25 | 4.31 | 4.36 | 4.42 |
| 125 | 3.86 | 3.91 | 3.97 | 4.02 | 4.08 | 4.13 | 4.18 | 4.24 |
| 130 | 3.70 | 3.75 | 3.81 | 3.86 | 3.91 | 3.96 | 4.01 | 4.07 |
| 135 | 3.55 | 3.61 | 3.66 | 3.71 | 3.78 | 3.81 | 3.86 | 3.91 |
| 140 | 3.42 | 3.47 | 3.52 | 3.57 | 3.62 | 3.67 | 3.72 | 3.77 |
| 145 | 3.29 | 3.34 | 3.39 | 3.44 | 3.49 | 3.54 | 3.58 | 3.63 |
| 150 | 3.18 | 3.23 | 3.27 | 3.32 | 3.36 | 3.41 | 3.46 | 3.50 |
| 155 | 3.07 | 3.11 | 3.16 | 3.21 | 3.25 | 3.30 | 3.34 | 3.39 |
| 160 | 2.97 | 3.01 | 3.06 | 3.10 | 3.15 | 3.19 | 3.23 | 3.27 |
| 165 | 2.87 | 2.91 | 2.95 | 3.00 | 3.05 | 3.09 | 3.13 | 3.17 |
| 170 | 2.78 | 2.82 | 2.87 | 2.91 | 2.95 | 2.99 | 3.03 | 3.07 |
| 175 | 2.69 | 2.73 | 2.78 | 2.82 | 2.86 | 2.90 | 2.94 | 2.98 |
| 180 | 2.61 | 2.65 | 2.69 | 2.73 | 2.77 | 2.81 | 2.85 | 2.89 |
| 185 | 2.54 | 2.58 | 2.62 | 2.66 | 2.69 | 2.73 | 2.77 | 2.81 |
| 190 | 2.46 | 2.50 | 2.54 | 2.58 | 2.62 | 2.66 | 2.69 | 2.73 |
| 195 | 2.39 | 2.43 | 2.47 | 2.51 | 2.55 | 2.58 | 2.62 | 2.66 |
| 200 | | 2.37 | 2.41 | 2.44 | 2.48 | 2.51 | 2.55 | 2.59 |
| 210 | | 2.24 | 2.28 | 2.31 | 2.35 | 2.38 | 2.42 | 2.45 |
| 220 | | 2.13 | 2.17 | 2.20 | 2.23 | 2.27 | 2.30 | 3.33 |
| 230 | | | 2.06 | 2.10 | 2.13 | 2.16 | 2.19 | 2.23 |
| 240 | | | | 2.00 | 2.03 | 2.06 | 2.09 | 2.13 |
| 250 | | | | 1.91 | 1.94 | 1.97 | 2.00 | 2.03 |
| 260 | | | | 1.83 | 1.86 | 1.89 | 1.92 | 1.95 |
| 270 | | | | 1.75 | 1.78 | 1.81 | 1.84 | 1.87 |
| 280 | | | | 1.68 | 1.71 | 1.74 | 1.77 | 1.80 |
| 290 | | | | 1.62 | 1.65 | 1.67 | 1.70 | 1.73 |
| 300 | | | | 1.56 | 1.59 | 1.61 | 1.64 | 1.66 |

| Pressure lb. per sq. in. | 930 | 940 | 950 | 960 | 970 | 980 | 990 | 1000 |
|---|---|---|---|---|---|---|---|---|
| 72 | 6.56 | 7.64 | 7.73 | 7.82 | 7.91 | 7.99 | 8.08 | 8.17 |
| 74 | 7.35 | 7.43 | 7.52 | 7.60 | 7.69 | 7.77 | 7.85 | 7.94 |
| 76 | 7.15 | 7.23 | 7.32 | 7.40 | 7.48 | 7.57 | 7.65 | 7.73 |
| 78 | 6.96 | 7.05 | 7.13 | 7.21 | 7.29 | 7.37 | 7.45 | 7.53 |
| 80 | 6.79 | 6.87 | 6.94 | 7.02 | 7.10 | 7.18 | 7.26 | 7.34 |
| 82 | 6.62 | 6.69 | 6.77 | 6.85 | 6.93 | 7.00 | 7.08 | 7.16 |
| 84 | 6.46 | 6.53 | 6.60 | 6.68 | 6.76 | 6.83 | 6.91 | 6.98 |
| 86 | 6.30 | 6.38 | 6.45 | 6.52 | 6.60 | 6.67 | 6.75 | 6.82 |
| 88 | 6.16 | 6.23 | 6.30 | 6.37 | 6.45 | 6.52 | 6.58 | 6.66 |
| 90 | 6.02 | 6.09 | 6.16 | 6.23 | 6.30 | 6.37 | 6.44 | 6.55 |
| 92 | 5.88 | 5.85 | 6.02 | 6.09 | 6.16 | 6.23 | 6.30 | 6.37 |
| 94 | 5.75 | 5.82 | 5.89 | 5.96 | 6.03 | 6.09 | 6.16 | 6.23 |
| 96 | 5.63 | 5.70 | 5.76 | 5.83 | 5.90 | 5.96 | 6.02 | 6.10 |
| 98 | 5.51 | 5.58 | 5.64 | 5.71 | 5.78 | 5.84 | 5.90 | 5.97 |
| 100 | 5.40 | 5.46 | 5.54 | 5.59 | 5.66 | 5.72 | 5.78 | 5.85 |
| 105 | 5.14 | 5.20 | 5.26 | 5.32 | 5.38 | 5.44 | 5.50 | 5.56 |
| 110 | 4.90 | 4.95 | 5.01 | 5.07 | 5.13 | 5.19 | 5.25 | 5.31 |
| 115 | 4.68 | 4.73 | 4.79 | 4.85 | 4.90 | 4.96 | 5.01 | 5.07 |
| 120 | 4.47 | 4.53 | 4.58 | 4.64 | 4.69 | 4.75 | 4.80 | 4.85 |
| 125 | 4.29 | 4.34 | 4.39 | 4.45 | 4.50 | 4.55 | 4.60 | 4.66 |
| 130 | 4.12 | 4.17 | 4.22 | 4.27 | 4.32 | 4.37 | 4.42 | 4.47 |
| 135 | 3.96 | 4.01 | 4.06 | 4.11 | 4.16 | 4.20 | 4.25 | 4.30 |
| 140 | 3.81 | 3.86 | 3.91 | 3.97 | 4.00 | 4.05 | 4.10 | 4.14 |
| 145 | 3.68 | 3.72 | 3.77 | 3.81 | 3.86 | 3.91 | 3.95 | 4.00 |
| 150 | 3.55 | 3.59 | 3.64 | 3.68 | 3.73 | 3.78 | 3.82 | 3.86 |
| 155 | 3.43 | 3.47 | 3.52 | 3.56 | 3.60 | 3.65 | 3.69 | 3.73 |
| 160 | 3.32 | 3.36 | 3.40 | 3.44 | 3.48 | 3.52 | 3.57 | 3.61 |
| 165 | 3.21 | 3.25 | 3.30 | 3.34 | 3.38 | 3.42 | 3.46 | 3.50 |
| 170 | 3.11 | 3.15 | 3.19 | 3.23 | 3.27 | 3.31 | 3.35 | 3.39 |
| 175 | 3.02 | 3.06 | 3.10 | 3.14 | 3.18 | 3.21 | 3.25 | 3.29 |
| 180 | 2.93 | 2.97 | 3.01 | 3.05 | 3.09 | 3.12 | 3.16 | 3.19 |
| 185 | 2.85 | 2.89 | 2.92 | 2.96 | 3.00 | 3.03 | 3.07 | 3.11 |
| 190 | 2.77 | 2.81 | 2.84 | 2.88 | 2.91 | 2.95 | 2.98 | 3.02 |
| 195 | 2.69 | 2.73 | 2.77 | 2.80 | 2.84 | 2.87 | 2.91 | 2.94 |
| 200 | 2.62 | 2.66 | 2.70 | 2.73 | 2.77 | 2.81 | 2.83 | 2.86 |
| 210 | 2.49 | 2.52 | 2.56 | 2.59 | 2.62 | 2.65 | 2.69 | 2.72 |
| 220 | 2.37 | 2.40 | 2.43 | 2.46 | 2.50 | 2.53 | 2.56 | 2.59 |
| 230 | 2.26 | 2.29 | 2.32 | 2.35 | 2.38 | 2.41 | 2.44 | 2.47 |
| 240 | 2.16 | 2.19 | 2.22 | 2.25 | 2.28 | 2.31 | 2.34 | 2.36 |
| 250 | 2.06 | 2.09 | 2.12 | 2.15 | 2.18 | 2.21 | 2.24 | 2.26 |
| 260 | 1.98 | 2.00 | 2.03 | 2.06 | 2.09 | 2.12 | 2.15 | 2.17 |
| 270 | 1.90 | 1.92 | 1.95 | 1.98 | 2.01 | 2.03 | 2.06 | 2.09 |
| 280 | 1.83 | 1.85 | 1.88 | 1.90 | 1.93 | 1.95 | 1.98 | 2.00 |
| 290 | 1.76 | 1.78 | 1.81 | 1.83 | 1.86 | 1.88 | 1.91 | 1.93 |
| 300 | 1.69 | 1.71 | 1.74 | 1.76 | 1.79 | 1.81 | 1.84 | 1.86 |

| Pressure lb. per sq. in. | 1050 | 1100 | 1150 | 1200 |
|---|---|---|---|---|
| 72 | 8.60 | 9.02 | 9.45 | 9.87 |
| 74 | 8.37 | 8.78 | 9.19 | 9.60 |
| 76 | 8.14 | 8.54 | 8.95 | 9.35 |
| 78 | 8.03 | 8.32 | 8.72 | 9.11 |
| 80 | 7.73 | 8.11 | 8.50 | 8.88 |
| 82 | 7.54 | 7.91 | 8.29 | 8.66 |
| 84 | 7.36 | 7.72 | 8.10 | 8.45 |
| 86 | 7.18 | 7.54 | 7.90 | 8.25 |
| 88 | 7.02 | 7.37 | 7.72 | 8.06 |
| 90 | 6.86 | 7.20 | 7.54 | 7.89 |
| 92 | 6.71 | 7.04 | 7.38 | 7.71 |
| 94 | 6.66 | 6.89 | 7.22 | 7.55 |
| 96 | 6.41 | 6.75 | 7.07 | 7.39 |
| 98 | 6.29 | 6.60 | 6.92 | 7.24 |
| 100 | 6.16 | 6.47 | 6.78 | 7.09 |
| 105 | 5.86 | 6.16 | 6.46 | 6.75 |
| 110 | 5.59 | 5.88 | 6.16 | 6.44 |
| 115 | 5.35 | 5.62 | 5.89 | 6.16 |
| 120 | 5.12 | 5.38 | 5.64 | 5.90 |
| 125 | 4.91 | 5.16 | 5.41 | 5.66 |
| 130 | 4.72 | 4.96 | 5.20 | 5.44 |
| 135 | 4.54 | 4.79 | 5.01 | 5.24 |
| 140 | 4.37 | 4.60 | 4.82 | 5.05 |
| 145 | 4.22 | 4.43 | 4.66 | 4.87 |
| 150 | 4.08 | 4.29 | 4.50 | 4.71 |
| 155 | 3.94 | 4.15 | 4.35 | 4.55 |
| 160 | 3.81 | 4.01 | 4.21 | 4.41 |
| 165 | 3.69 | 3.89 | 4.08 | 4.27 |
| 170 | 3.58 | 3.77 | 3.96 | 4.14 |
| 175 | 3.47 | 3.66 | 3.84 | 4.02 |
| 180 | 3.37 | 3.56 | 3.73 | 3.91 |
| 185 | 3.28 | 3.46 | 3.63 | 3.80 |
| 190 | 3.20 | 3.37 | 3.53 | 3.70 |
| 195 | 3.11 | 3.28 | 3.44 | 3.60 |
| 200 | 3.03 | 3.19 | 3.35 | 3.51 |
| 210 | 2.88 | 3.04 | 3.19 | 3.34 |
| 220 | 2.74 | 2.89 | 3.04 | 3.19 |
| 230 | 2.89 | 2.76 | 2.91 | 3.05 |
| 240 | 2.50 | 2.64 | 2.78 | 2.92 |
| 250 | 2.40 | 2.54 | 2.67 | 2.80 |
| 260 | 2.28 | 2.43 | 2.56 | 2.69 |
| 270 | 2.22 | 2.34 | 2.46 | 2.58 |
| 280 | 2.13 | 2.25 | 2.37 | 2.49 |
| 290 | 2.05 | 2.17 | 2.29 | 2.40 |
| 300 | 1.98 | 2.09 | 2.21 | 2.32 |

TABLE II

SUPERHEATED STEAM

Entropy in English Units.

| Pressure lb. per sq. in. | Absolute Temperatures - Fahrenheit Scale. 590 | 600 | 610 | 620 | 630 | 640 | 650 | 660 |
|---|---|---|---|---|---|---|---|---|
| 1 | 2.0017 | 2.0090 | 2.0162 | 2.0233 | 2.0303 | 2.0371 | 2.0440 | 2.0493 |
| 2 | 1.9244 | 1.9319 | 1.9392 | 1.9463 | 1.9534 | 1.9602 | 1.9671 | 1.9738 |
| 3 | | 1.8866 | 1.8939 | 1.9010 | 1.9081 | 1.9150 | 1.9219 | 1.9286 |
| 4 | | | | 1.8686 | 1.8758 | 1.8828 | 1.8898 | 1.8965 |
| 5 | | | | | 1.8500 | 1.8573 | 1.8647 | 1.8715 |
| 6 | | | | | 1.8291 | 1.8366 | 1.8441 | 1.8509 |
| 7 | | | | | | 1.8192 | 1.8267 | 1.8335 |
| 8 | | | | | | | 1.8115 | 1.8184 |
| 9 | | | | | | | 1.7978 | 1.8050 |
| 10 | | | | | | | | 1.7929 |
| 11 | | | | | | | | 1.7819 |
| 12 | | | | | | | | |
| 13 | | | | | | | | |
| 14 | | | | | | | | |
| 15 | | | | | | | | |
| 20 | | | | | | | | |
| 24 | | | | | | | | |
| 28 | | | | | | | | |
| 32 | | | | | | | | |
| 40 | | | | | | | | |
| 50 | | | | | | | | |
| 60 | | | | | | | | |
| 70 | | | | | | | | |
| 80 | | | | | | | | |
| 90 | | | | | | | | |
| 100 | | | | | | | | |
| 110 | | | | | | | | |
| 120 | | | | | | | | |
| 130 | | | | | | | | |
| 140 | | | | | | | | |
| 150 | | | | | | | | |
| 160 | | | | | | | | |
| 170 | | | | | | | | |
| 180 | | | | | | | | |
| 190 | | | | | | | | |
| 200 | | | | | | | | |
| 220 | | | | | | | | |
| 240 | | | | | | | | |
| 260 | | | | | | | | |
| 280 | | | | | | | | |
| 300 | | | | | | | | |

| Pressure lb. per sq. in. | 670 | 680 | 690 | 700 | 710 | 720 | 730 | 740 |
|---|---|---|---|---|---|---|---|---|
| 1 | 2.0574 | | | | | | | |
| 2 | 1.9805 | 1.9872 | | | | | | |
| 3 | 1.9354 | 1.9419 | 1.9485 | | | | | |
| 4 | 1.9033 | 1.9098 | 1.9164 | 1.9223 | | | | |
| 5 | 1.8783 | 1.8848 | 1.8914 | 1.8979 | | | | |
| 6 | 1.8578 | 1.8644 | 1.8710 | 1.8775 | | | | |
| 7 | 1.8404 | 1.8470 | 1.8536 | 1.8602 | 1.8666 | | | |
| 8 | 1.8253 | 1.8319 | 1.8386 | 1.8451 | 1.8516 | 1.8579 | | |
| 9 | 1.8119 | 1.8185 | 1.8252 | 1.8317 | 1.8383 | 1.8447 | 1.8512 | |
| 10 | 1.7999 | 1.8066 | 1.8133 | 1.8198 | 1.8263 | 1.8327 | 1.8390 | 1.8453 |
| 11 | 1.7889 | 1.7956 | 1.8024 | 1.8089 | 1.8155 | 1.8218 | 1.8282 | 1.8345 |
| 12 | 1.7790 | 1.7857 | 1.7924 | 1.7990 | 1.8057 | 1.8120 | 1.8184 | 1.8246 |
| 13 | 1.7697 | 1.7765 | 1.7833 | 1.7899 | 1.7965 | 1.8029 | 1.8093 | 1.8155 |
| 14 | | 1.7678 | 1.7747 | 1.7813 | 1.7880 | 1.7944 | 1.8008 | 1.8069 |
| 15 | | 1.7599 | 1.7668 | 1.7734 | 1.7801 | 1.7865 | 1.7930 | 1.7992 |
| 20 | | | 1.7333 | 1.7401 | 1.7469 | 1.7534 | 1.7599 | 1.7662 |
| 24 | | | | 1.7187 | 1.7253 | 1.7320 | 1.7387 | 1.7451 |
| 28 | | | | | 1.7072 | 1.7138 | 1.7206 | 1.7271 |
| 32 | | | | | | 1.6981 | 1.7048 | 1.7113 |
| 40 | | | | | | | 1.6779 | 1.6844 |
| 50 | | | | | | | | |
| 60 | | | | | | | | |
| 70 | | | | | | | | |
| 80 | | | | | | | | |
| 90 | | | | | | | | |
| 100 | | | | | | | | |
| 110 | | | | | | | | |
| 120 | | | | | | | | |
| 130 | | | | | | | | |
| 140 | | | | | | | | |
| 150 | | | | | | | | |
| 160 | | | | | | | | |
| 170 | | | | | | | | |
| 180 | | | | | | | | |
| 190 | | | | | | | | |
| 200 | | | | | | | | |
| 220 | | | | | | | | |
| 240 | | | | | | | | |
| 260 | | | | | | | | |
| 280 | | | | | | | | |
| 300 | | | | | | | | |

| Pressure lb. per sq. in. | 750 | 760 | 770 | 780 | 790 | 800 | 810 | 820 |
|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
| 4 | | | | | | | | |
| 5 | | | | | | | | |
| 6 | | | | | | | | |
| 7 | | | | | | | | |
| 8 | | | | | | | | |
| 9 | | | | | | | | |
| 10 | | | | | | | | |
| 11 | 1.8408 | | | | | | | |
| 12 | 1.8310 | 1.8368 | | | | | | |
| 13 | 1.8217 | 1.8278 | 1.8339 | | | | | |
| 14 | 1.8130 | 1.8193 | 1.8255 | 1.8314 | 1.8374 | | | |
| 15 | 1.8054 | 1.8115 | 1.8177 | 1.8236 | 1.8296 | 1.8354 | 1.8412 | |
| 20 | 1.7725 | 1.7787 | 1.7849 | 1.7909 | 1.7969 | 1.8028 | 1.8086 | 1.8146 |
| 24 | 1.7515 | 1.7577 | 1.7639 | 1.7700 | 1.7760 | 1.7819 | 1.7878 | 1.7935 |
| 28 | 1.7335 | 1.7397 | 1.7460 | 1.7521 | 1.7583 | 1.7642 | 1.7701 | 1.7759 |
| 32 | 1.7178 | 1.7241 | 1.7304 | 1.7366 | 1.7428 | 1.7487 | 1.7547 | 1.7605 |
| 40 | 1.6912 | 1.6976 | 1.7041 | 1.7104 | 1.7166 | 1.7227 | 1.7287 | 1.7346 |
| 50 | 1.6640 | 1.6708 | 1.6772 | 1.6837 | 1.6900 | 1.6963 | 1.7024 | 1.7084 |
| 60 | | 1.6484 | 1.6550 | 1.6615 | 1.6679 | 1.6743 | 1.6805 | 1.6866 |
| 70 | | | 1.6357 | 1.6425 | 1.6490 | 1.6554 | 1.6616 | 1.6679 |
| 80 | | | | 1.6256 | 1.6322 | 1.6388 | 1.6451 | 1.6515 |
| 90 | | | | 1.6105 | 1.6172 | 1.6239 | 1.6304 | 1.6369 |
| 100 | | | | | 1.6037 | 1.6102 | 1.6168 | 1.6235 |
| 110 | | | | | | 1.5980 | 1.6046 | 1.6113 |
| 120 | | | | | | | 1.5932 | 1.6000 |
| 130 | | | | | | | 1.5827 | 1.5894 |
| 140 | | | | | | | | 1.5795 |
| 150 | | | | | | | | 1.5702 |
| 160 | | | | | | | | |
| 170 | | | | | | | | |
| 180 | | | | | | | | |
| 190 | | | | | | | | |
| 200 | | | | | | | | |
| 220 | | | | | | | | |
| 240 | | | | | | | | |
| 260 | | | | | | | | |
| 280 | | | | | | | | |
| 300 | | | | | | | | |

| Pressure lb. per sq. in. | 830 | 840 | 850 | 860 | 870 | 880 | 890 | 900 |
|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
| 4 | | | | | | | | |
| 5 | | | | | | | | |
| 6 | | | | | | | | |
| 7 | | | | | | | | |
| 8 | | | | | | | | |
| 9 | | | | | | | | |
| 10 | | | | | | | | |
| 11 | | | | | | | | |
| 12 | | | | | | | | |
| 13 | | | | | | | | |
| 14 | | | | | | | | |
| 15 | | | | | | | | |
| 20 | 1.8200 | 1.8256 | 1.8312 | 1.8367 | | | | |
| 24 | 1.7993 | 1.8049 | 1.8105 | 1.8160 | 1.8215 | 1.8269 | 1.8325 | |
| 28 | 1.7817 | 1.7873 | 1.7930 | 1.7985 | 1.8040 | 1.8094 | 1.8148 | 1.8201 |
| 32 | 1.7663 | 1.7720 | 1.7777 | 1.7833 | 1.7887 | 1.7942 | 1.7996 | 1.8049 |
| 40 | 1.7405 | 1.7462 | 1.7519 | 1.7576 | 1.7631 | 1.7686 | 1.7740 | 1.7794 |
| 50 | 1.7143 | 1.7202 | 1.7256 | 1.7317 | 1.7372 | 1.7428 | 1.7483 | 1.7538 |
| 60 | 1.6926 | 1.6986 | 1.7044 | 1.7102 | 1.7159 | 1.7215 | 1.7271 | 1.7326 |
| 70 | 1.6740 | 1.6801 | 1.6860 | 1.6919 | 1.6976 | 1.7033 | 1.7088 | 1.7143 |
| 80 | 1.6576 | 1.6638 | 1.6698 | 1.6758 | 1.6816 | 1.6874 | 1.6930 | 1.6986 |
| 90 | 1.6431 | 1.6494 | 1.6554 | 1.6614 | 1.6673 | 1.6732 | 1.6789 | 1.6846 |
| 100 | 1.6298 | 1.6362 | 1.6423 | 1.6485 | 1.6543 | 1.6602 | 1.6660 | 1.6718 |
| 110 | 1.6177 | 1.6241 | 1.6303 | 1.6366 | 1.6425 | 1.6485 | 1.6542 | 1.6600 |
| 120 | 1.6065 | 1.6130 | 1.6193 | 1.6256 | 1.6316 | 1.6377 | 1.6435 | 1.6493 |
| 130 | 1.5960 | 1.6026 | 1.6089 | 1.6153 | 1.6214 | 1.6276 | 1.6335 | 1.6395 |
| 140 | 1.5862 | 1.5929 | 1.5993 | 1.6058 | 1.6119 | 1.6181 | 1.6241 | 1.6302 |
| 150 | 1.5769 | 1.5837 | 1.5902 | 1.5967 | 1.6030 | 1.6093 | 1.6154 | 1.6215 |
| 160 | 1.5681 | 1.5750 | 1.5816 | 1.5882 | 1.5945 | 1.6009 | 1.6065 | 1.6121 |
| 170 | 1.5597 | 1.5667 | 1.5734 | 1.5801 | 1.5865 | 1.5929 | 1.5991 | 1.6053 |
| 180 | | 1.5590 | 1.5656 | 1.5723 | 1.5794 | 1.5858 | 1.5918 | 1.5978 |
| 190 | | 1.5516 | 1.5582 | 1.5650 | 1.5714 | 1.5780 | 1.5843 | 1.5906 |
| 200 | | | 1.5524 | 1.5580 | 1.5645 | 1.5710 | 1.5774 | 1.5838 |
| 220 | | | 1.5372 | 1.5443 | 1.5511 | 1.5579 | 1.5644 | 1.5709 |
| 240 | | | | 1.5318 | 1.5387 | 1.5456 | 1.5522 | 1.5589 |
| 260 | | | | | 1.5286 | 1.5341 | 1.5408 | 1.5476 |
| 280 | | | | | | 1.5231 | 1.5300 | 1.5369 |
| 300 | | | | | | 1.5143 | 1.5208 | 1.5278 |

| Pressure lb. per sq. in. | 910 | 920 | 930 | 940 | 950 | 960 | 970 | 980 |
|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
| 4 | | | | | | | | |
| 5 | | | | | | | | |
| 6 | | | | | | | | |
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| 12 | | | | | | | | |
| 13 | | | | | | | | |
| 14 | | | | | | | | |
| 15 | | | | | | | | |
| 20 | | | | | | | | |
| 24 | | | | | | | | |
| 28 | 1.8253 | 1.8305 | | | | | | |
| 32 | 1.8101 | 1.8154 | 1.8206 | 1.8257 | 1.8308 | | | |
| 40 | 1.7847 | 1.7900 | 1.7952 | 1.8004 | 1.8059 | 1.8105 | 1.8156 | 1.8206 |
| 50 | 1.7591 | 1.7644 | 1.7703 | 1.7749 | 1.7800 | 1.7851 | 1.7901 | 1.7952 |
| 60 | 1.7379 | 1.7433 | 1.7486 | 1.7539 | 1.7585 | 1.7632 | 1.7688 | 1.7744 |
| 70 | 1.7193 | 1.7244 | 1.7297 | 1.7354 | 1.7412 | 1.7466 | 1.7520 | 1.7566 |
| 80 | 1.7041 | 1.7096 | 1.7150 | 1.7204 | 1.7256 | 1.7308 | 1.7360 | 1.7411 |
| 90 | 1.6901 | 1.6956 | 1.7018 | 1.7062 | 1.7112 | 1.7164 | 1.7216 | 1.7273 |
| 100 | 1.6774 | 1.6830 | 1.6884 | 1.6939 | 1.6992 | 1.7045 | 1.7096 | 1.7148 |
| 110 | 1.6657 | 1.6715 | 1.6769 | 1.6824 | 1.6873 | 1.6932 | 1.6984 | 1.7037 |
| 120 | 1.6550 | 1.6607 | 1.6663 | 1.6720 | 1.6774 | 1.6828 | 1.6880 | 1.6933 |
| 130 | 1.6452 | 1.6510 | 1.6566 | 1.6622 | 1.6676 | 1.6731 | 1.6784 | 1.6837 |
| 140 | 1.6360 | 1.6418 | 1.6474 | 1.6531 | 1.6585 | 1.6640 | 1.6694 | 1.6748 |
| 150 | 1.6268 | 1.6333 | 1.6384 | 1.6447 | 1.6500 | 1.6557 | 1.6610 | 1.6663 |
| 160 | 1.6185 | 1.6250 | 1.6307 | 1.6365 | 1.6420 | 1.6476 | 1.6530 | 1.6585 |
| 170 | 1.6112 | 1.6172 | 1.6230 | 1.6288 | 1.6344 | 1.6400 | 1.6455 | 1.6510 |
| 180 | 1.6038 | 1.6098 | 1.6156 | 1.6224 | 1.6276 | 1.6329 | 1.6384 | 1.6439 |
| 190 | 1.5967 | 1.6028 | 1.6087 | 1.6146 | 1.6203 | 1.6260 | 1.6315 | 1.6371 |
| 200 | 1.5899 | 1.5961 | 1.6020 | 1.6080 | 1.6137 | 1.6195 | 1.6250 | 1.6306 |
| 220 | 1.5771 | 1.5834 | 1.5894 | 1.5954 | 1.6012 | 1.6071 | 1.6128 | 1.6185 |
| 240 | 1.5652 | 1.5716 | 1.5777 | 1.5839 | 1.5898 | 1.5957 | 1.6014 | 1.6072 |
| 260 | 1.5541 | 1.5606 | 1.5668 | 1.5731 | 1.5791 | 1.5851 | 1.5909 | 1.5967 |
| 280 | 1.5435 | 1.5501 | 1.5564 | 1.5628 | 1.5689 | 1.5750 | 1.5909 | 1.5869 |
| 300 | 1.5339 | 1.5401 | 1.5466 | 1.5531 | 1.5593 | 1.5655 | 1.5715 | 1.5775 |

| Pressure lb. per sq. in. | 990 | 1000 | 1050 | 1100 | 1150 | 1200 |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
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| 14 | | | | | | |
| 15 | | | | | | |
| 20 | | | | | | |
| 24 | | | | | | |
| 28 | | | | | | |
| 32 | | | | | | |
| 40 | 1.8254 | 1.8303 | | | | |
| 50 | 1.8001 | 1.8050 | 1.8288 | | | |
| 60 | 1.7793 | 1.7842 | 1.8076 | 1.8310 | 1.8526 | 1.8743 |
| 70 | 1.7616 | 1.7666 | 1.7901 | 1.8136 | 1.8353 | 1.8570 |
| 80 | 1.7462 | 1.7511 | 1.7747 | 1.7982 | 1.8201 | 1.8421 |
| 90 | 1.7324 | 1.7376 | 1.7613 | 1.7850 | 1.8068 | 1.8286 |
| 100 | 1.7199 | 1.7251 | 1.7490 | 1.7729 | 1.7948 | 1.8167 |
| 110 | 1.7088 | 1.7139 | 1.7380 | 1.7620 | 1.7839 | 1.8059 |
| 120 | 1.6984 | 1.7036 | 1.7277 | 1.7519 | 1.7739 | 1.7960 |
| 130 | 1.6889 | 1.6941 | 1.7183 | 1.7426 | 1.7652 | 1.7878 |
| 140 | 1.6800 | 1.6852 | 1.7095 | 1.7339 | 1.7561 | 1.7784 |
| 150 | 1.6714 | 1.6765 | 1.7012 | 1.7259 | 1.7481 | 1.7704 |
| 160 | 1.6637 | 1.6690 | 1.6936 | 1.7182 | 1.7406 | 1.7630 |
| 170 | 1.6563 | 1.6616 | 1.6863 | 1.7111 | 1.7335 | 1.7560 |
| 180 | 1.6492 | 1.6546 | 1.6795 | 1.7044 | 1.7269 | 1.7494 |
| 190 | 1.6425 | 1.6479 | 1.6730 | 1.6981 | 1.7206 | 1.7431 |
| 200 | 1.6360 | 1.6415 | 1.6666 | 1.6918 | 1.7144 | 1.7371 |
| 220 | 1.6235 | 1.6285 | 1.6540 | 1.6792 | 1.7026 | 1.7259 |
| 240 | 1.6128 | 1.6184 | 1.6440 | 1.6697 | 1.6927 | 1.7157 |
| 260 | 1.6023 | 1.6080 | 1.6339 | 1.6599 | 1.6830 | 1.7062 |
| 280 | 1.5926 | 1.5983 | 1.6245 | 1.6507 | 1.6740 | 1.6973 |
| 300 | 1.5833 | 1.5891 | 1.6156 | 1.6421 | 1.6655 | 1.6390 |

TABLE III.

SUPERHEATED STEAM.

Heat Content in English Units

| Pressure lb. per sq. in. | Absolute Temperatures - Fahrenheit Scale. 590 | 600 | 610 | 620 | 630 | 640 | 650 |
|---|---|---|---|---|---|---|---|
| 1 | 1118.75 | 1123.09 | 1127.45 | 1131.81 | 1136.18 | 1140.56 | 1144.95 |
| 2 | 1118.2 | 1122.60 | 1126.98 | 1131.36 | 1135.76 | 1140.16 | 1144.57 |
| 3 | | 1122.09 | 1126.50 | 1130.92 | 1135.33 | 1139.76 | 1144.19 |
| 4 | | | | 1130.47 | 1134.91 | 1139.36 | 1143.81 |
| 5 | | | | | 1134.49 | 1138.96 | 1143.43 |
| 6 | | | | | 1134.06 | 1138.56 | 1143.05 |
| 7 | | | | | | 1138.22 | 1142.70 |
| 8 | | | | | | | 1142.28 |
| 9 | | | | | | | 1141.95 |
| 10 | | | | | | | |
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| 32 | | | | | | | |
| 40 | | | | | | | |
| 50 | | | | | | | |
| 60 | | | | | | | |
| 70 | | | | | | | |
| 80 | | | | | | | |
| 90 | | | | | | | |
| 100 | | | | | | | |
| 110 | | | | | | | |
| 120 | | | | | | | |
| 130 | | | | | | | |
| 140 | | | | | | | |
| 150 | | | | | | | |
| 160 | | | | | | | |
| 170 | | | | | | | |
| 180 | | | | | | | |
| 190 | | | | | | | |
| 200 | | | | | | | |
| 220 | | | | | | | |
| 240 | | | | | | | |
| 260 | | | | | | | |
| 280 | | | | | | | |
| 300 | | | | | | | |

| Pressure lb. per sq. in. | 660 | 670 | 680 | 690 | 700 | 710 | 720 |
|---|---|---|---|---|---|---|---|
| 1 | 1149.35 | 1153.74 | | | | | |
| 2 | 1148.98 | 1153.40 | 1157.84 | | | | |
| 3 | 1148.62 | 1153.06 | 1157.51 | 1161.96 | | | |
| 4 | 1148.26 | 1152.72 | 1157.22 | 1161.65 | 1166.13 | | |
| 5 | 1147.90 | 1152.40 | 1156.90 | 1161.37 | 1165.84 | | |
| 6 | 1147.54 | 1152.06 | 1156.58 | 1161.06 | 1165.54 | | |
| 7 | 1147.18 | 1151.72 | 1156.26 | 1160.75 | 1165.24 | 1169.77 | |
| 8 | 1146.82 | 1151.38 | 1155.94 | 1160.44 | 1164.95 | 1169.49 | 1174.03 |
| 9 | 1146.46 | 1151.04 | 1155.62 | 1160.14 | 1164.66 | 1169.21 | 1173.77 |
| 10 | 1146.10 | 1150.70 | 1155.30 | 1159.83 | 1164.36 | 1168.92 | 1173.50 |
| 11 | 1145.75 | 1150.32 | 1154.90 | 1159.49 | 1164.07 | 1168.65 | 1173.23 |
| 12 | | 1149.98 | 1154.58 | 1159.18 | 1163.77 | 1168.37 | 1172.96 |
| 13 | | 1149.63 | 1154.25 | 1158.87 | 1163.48 | 1168.09 | 1172.70 |
| 14 | | | 1153.59 | 1158.56 | 1163.18 | 1167.81 | 1172.43 |
| 15 | | | 1153.59 | 1158.25 | 2262.84 | 1167.53 | 1172.16 |
| 20 | | | | 1156.69 | 1161.40 | 1166.12 | 1170.82 |
| 24 | | | | | 1160.21 | 1164.99 | 1169.74 |
| 28 | | | | | | 1163.86 | 1168.66 |
| 32 | | | | | | | 1167.57 |
| 40 | | | | | | | |
| 50 | | | | | | | |
| 60 | | | | | | | |
| 70 | | | | | | | |
| 80 | | | | | | | |
| 90 | | | | | | | |
| 100 | | | | | | | |
| 110 | | | | | | | |
| 120 | | | | | | | |
| 130 | | | | | | | |
| 140 | | | | | | | |
| 150 | | | | | | | |
| 160 | | | | | | | |
| 170 | | | | | | | |
| 180 | | | | | | | |
| 190 | | | | | | | |
| 200 | | | | | | | |
| 220 | | | | | | | |
| 240 | | | | | | | |
| 260 | | | | | | | |
| 280 | | | | | | | |
| 300 | | | | | | | |

| Pressure lb. per sq. in. | 730 | 740 | 750 | 760 | 770 | 780 | 790 |
|---|---|---|---|---|---|---|---|
| 1 | | | | | | | |
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| 7 | | | | | | | |
| 8 | | | | | | | |
| 9 | 1178.32 | | | | | | |
| 10 | 1178.07 | 1182.65 | | | | | |
| 11 | 1177.82 | 1182.40 | 1186.98 | | | | |
| 12 | 1177.56 | 1182.16 | 1186.76 | 1191.38 | | | |
| 13 | 1177.31 | 1181.92 | 1186.53 | 1191.14 | 1195.75 | | |
| 14 | 1177.05 | 1181.67 | 1186.29 | 1190.91 | 1195.54 | 1200.16 | 1204.79 |
| 15 | 1176.80 | 1181.43 | 1186.06 | 1190.69 | 1195.33 | 1199.96 | 1204.60 |
| 20 | 1175.52 | 1180.21 | 1184.90 | 1189.58 | 1194.27 | 1198.95 | 1203.63 |
| 24 | 1174.50 | 1179.23 | 1183.97 | 1188.69 | 1193.42 | 1198.13 | 1202.85 |
| 28 | 1173.47 | 1178.25 | 1183.03 | 1187.79 | 1192.56 | 1197.31 | 1202.07 |
| 32 | 1172.43 | 1177.26 | 1182.09 | 1186.90 | 1191.71 | 1196.50 | 1201.29 |
| 40 | 1170.35 | 1175.27 | 1180.19 | 1185.18 | 1189.98 | 1194.84 | 1199.71 |
| 50 | | | 1177.84 | 1182.83 | 1187.83 | 1192.78 | 1197.74 |
| 60 | | | | 1180.57 | 1185.65 | 1190.70 | 1195.75 |
| 70 | | | | | 1183.46 | 1188.60 | 1193.75 |
| 80 | | | | | | 1186.50 | 1191.74 |
| 90 | | | | | | 1184.39 | 1189.71 |
| 100 | | | | | | | 1187.67 |
| 110 | | | | | | | |
| 120 | | | | | | | |
| 130 | | | | | | | |
| 140 | | | | | | | |
| 150 | | | | | | | |
| 160 | | | | | | | |
| 170 | | | | | | | |
| 180 | | | | | | | |
| 190 | | | | | | | |
| 200 | | | | | | | |
| 220 | | | | | | | |
| 240 | | | | | | | |
| 260 | | | | | | | |
| 280 | | | | | | | |
| 300 | | | | | | | |

| Pressure lb. per sq. in. | 800 | 810 | 820 | 830 | 840 | 850 | 860 |
|---|---|---|---|---|---|---|---|
| 1 | | | | | | | |
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| 10 | | | | | | | |
| 11 | | | | | | | |
| 12 | | | | | | | |
| 13 | | | | | | | |
| 14 | | | | | | | |
| 15 | 1209.24 | 1213.88 | | | | | |
| 20 | 1208.31 | 1212.99 | 1217.67 | 1222.36 | 1227.05 | 1231.74 | 1236.43 |
| 24 | 1207.56 | 1212.28 | 1216.99 | 1221.71 | 1226.42 | 1231.14 | 1235.86 |
| 28 | 1206.81 | 1211.56 | 1216.30 | 1221.05 | 1225.79 | 1230.53 | 1235.27 |
| 32 | 1206.07 | 1210.85 | 1215.62 | 1220.39 | 1225.16 | 1229.93 | 1284.69 |
| 40 | 1204.55 | 1209.40 | 1214.23 | 1219.06 | 1223.88 | 1228.71 | 1233.52 |
| 50 | 1202.67 | 1207.60 | 1212.50 | 1217.41 | 1222.30 | 1227.19 | 1232.06 |
| 60 | 1200.76 | 1205.78 | 1210.76 | 1215.74 | 1220.69 | 1225.65 | 1230.58 |
| 70 | 1198.84 | 1203.94 | 1208.94 | 1214.05 | 1219.07 | 1224.10 | 1229.09 |
| 80 | 1196.92 | 1202.10 | 1207.23 | 1212.36 | 1217.45 | 1222.54 | 1227.59 |
| 90 | 1194.80 | 1199.99 | 1205.32 | 1210.65 | 1215.82 | 1220.97 | 1226.08 |
| 100 | 1192.98 | 1198.37 | 1203.65 | 1208.93 | 1214.15 | 1219.38 | 1224.56 |
| 110 | 1191.04 | 1196.48 | 1201.84 | 1207.20 | 1212.30 | 1217.40 | 1222.84 |
| 120 | | 1194.57 | 1200.05 | 1205.45 | 1210.85 | 1216.20 | 1221.51 |
| 130 | | 1192.68 | 1198.22 | 1203.70 | 1209.18 | 1214.57 | 1219.96 |
| 140 | | | 1196.38 | 1201.93 | 1207.43 | 1212.94 | 1218.41 |
| 150 | | | 1194.53 | 1200.15 | 1205.78 | 1211.31 | 1216.84 |
| 160 | | | | 1198.36 | 1204.06 | 1209.66 | 1215.27 |
| 170 | | | | 1196.56 | 1202.34 | 1208.01 | 1213.68 |
| 180 | | | | | 1201.5 | 1207.01 | 1212.08 |
| 190 | | | | | 1199.90 | 1205.00 | 1210.47 |
| 200 | | | | | | 1203.70 | 1208.86 |
| 220 | | | | | | 1200.00 | 1205.60 |
| 240 | | | | | | | 1202.40 |
| 260 | | | | | | | |
| 280 | | | | | | | |
| 300 | | | | | | | |

| Pressure lb. per sq. in. | 870 | 880 | 890 | 900 | 910 | 920 | 930 |
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| 13 | | | | | | | |
| 14 | | | | | | | |
| 15 | | | | | | | |
| 20 | 1241.13 | | | | | | |
| 24 | 1240.58 | 1245.30 | 1250.03 | | | | |
| 28 | 1240.02 | 1244.77 | 1249.52 | 1254.27 | 1259.02 | 1263.71 | |
| 32 | 1239.46 | 1244.23 | 1249.00 | 1253.77 | 1258.55 | 1263.36 | 1268.18 |
| 40 | 1238.34 | 1243.40 | 1247.96 | 1252.77 | 1257.58 | 1262.39 | 1267.21 |
| 50 | 1236.93 | 1241.79 | 1246.66 | 1251.52 | 1256.39 | 1261.24 | 1266.10 |
| 60 | 1235.51 | 1240.43 | 1245.35 | 1250.26 | 1255.17 | 1260.07 | 1264.98 |
| 70 | 1234.09 | 1239.06 | 1244.03 | 1248.99 | 1253.95 | 1258.40 | 1263.85 |
| 80 | 1232.65 | 1237.68 | 1242.71 | 1247.71 | 1252.72 | 1257.71 | 1262.71 |
| 90 | 1231.20 | 1236.28 | 1241.37 | 1246.43 | 1251.49 | 1256.52 | 1261.56 |
| 100 | 1229.74 | 1234.88 | 1240.03 | 1245.13 | 1250.24 | 1255.32 | 1260.41 |
| 110 | 1228.28 | 1233.47 | 1238.67 | 1243.83 | 1248.99 | 1254.07 | 1259.25 |
| 120 | 1226.78 | 1232.07 | 1237.80 | 1242.53 | 1247.72 | 1252.91 | 1258.07 |
| 130 | 1225.30 | 1230.64 | 1235.92 | 1241.21 | 1246.45 | 1251.69 | 1256.69 |
| 140 | 1223.81 | 1229.21 | 1234.54 | 1239.88 | 1245.17 | 1250.46 | 1255.70 |
| 150 | 1222.30 | 1227.76 | 1233.15 | 1238.54 | 1243.68 | 1249.22 | 1254.51 |
| 160 | 1220.78 | 1226.30 | 1231.72 | 1237.15 | 1242.66 | 1247.98 | 1253.32 |
| 170 | 1219.26 | 1224.84 | 1230.34 | 1235.85 | 1241.29 | 1246.73 | 1252.11 |
| 180 | 1217.92 | 1223.36 | 1228.92 | 1234.48 | 1239.97 | 1245.47 | 1250.89 |
| 190 | 1216.17 | 1221.88 | 1227.49 | 1233.11 | 1238.60 | 1244.19 | 1249.67 |
| 200 | 1214.63 | 1220.39 | 1226.06 | 1231.73 | 1237.32 | 1242.92 | 1248.44 |
| 220 | 1211.49 | 1217.38 | 1223.17 | 1228.96 | 1234.65 | 1240.35 | 1245.96 |
| 240 | 1208.20 | 1214.33 | 1220.23 | 1226.13 | 1231.93 | 1237.73 | 1243.44 |
| 260 | 1205.30 | 1211.25 | 1217.26 | 1223.28 | 1229.18 | 1235.09 | 1240.85 |
| 280 | | 1208.12 | 1214.26 | 1220.40 | 1226.41 | 1232.42 | 1238.32 |
| 300 | | 1204.96 | 1211.22 | 1217.48 | 1223.59 | 1229.71 | 1235.71 |

| Pressure lb. per sq. in. | 940 | 950 | 960 | 970 | 980 | 990 | 1000 |
|---|---|---|---|---|---|---|---|
| 1 | | | | | | | |
| 2 | | | | | | | |
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| 14 | | | | | | | |
| 15 | | | | | | | |
| 20 | | | | | | | |
| 24 | | | | | | | |
| 28 | | | | | | | |
| 32 | 1272.98 | 1277.79 | | | | | |
| 40 | 1272.03 | 1276.85 | 1281.67 | 1286.49 | 1291.32 | 1296.15 | 1301.00 |
| 50 | 1270.96 | 1275.82 | 1280.68 | 1285.54 | 1290.40 | 1295.26 | 1300.14 |
| 60 | 1269.87 | 1274.77 | 1279.67 | 1284.57 | 1289.46 | 1294.36 | 1299.26 |
| 70 | 1268.78 | 1273.72 | 1278.65 | 1283.59 | 1288.52 | 1293.45 | 1298.38 |
| 80 | 1267.68 | 1272.66 | 1277.63 | 1282.61 | 1287.57 | 1292.54 | 1297.50 |
| 90 | 1266.58 | 1271.60 | 1276.61 | 1281.62 | 1286.62 | 1291.62 | 1296.61 |
| 100 | 1265.47 | 1270.53 | 1275.57 | 1280.62 | 1285.65 | 1290.69 | 1295.72 |
| 110 | 1264.35 | 1269.45 | 1274.53 | 1279.62 | 1284.69 | 1289.76 | 1294.82 |
| 120 | 1263.23 | 1268.36 | 1273.50 | 1278.61 | 1283.72 | 1288.81 | 1293.91 |
| 130 | 1262.10 | 1267.27 | 1272.44 | 1277.59 | 1282.74 | 1287.87 | 1293.00 |
| 140 | 1260.95 | 1266.16 | 1271.38 | 1276.56 | 1281.75 | 1286.91 | 1292.08 |
| 150 | 1259.81 | 1265.06 | 1270.32 | 1275.54 | 1280.76 | 1285.95 | 1291.15 |
| 160 | 1258.66 | 1263.95 | 1269.25 | 1274.50 | 1279.76 | 1284.99 | 1290.22 |
| 170 | 1257.49 | 1262.83 | 1268.17 | 1273.26 | 1278.76 | 1284.02 | 1289.29 |
| 180 | 1256.32 | 1261.70 | 1267.08 | 1272.41 | 1277.75 | 1283.04 | 1288.34 |
| 190 | 1255.15 | 1260.56 | 1265.98 | 1271.20 | 1276.73 | 1282.06 | 1287.40 |
| 200 | 1253.96 | 1259.42 | 1264.88 | [illegible] | [illegible] | 1281.07 | 1286.44 |
| 220 | 1251.58 | 1257.12 | 1262.67 | 1268.15 | 1273.64 | 1279.08 | 1284.52 |
| 240 | 1249.15 | 1254.78 | 1260.42 | 1265.98 | 1271.55 | 1277.06 | 1282.57 |
| 260 | 1246.71 | 1252.43 | 1258.15 | 1263.74 | 1269.43 | 1275.01 | 1280.60 |
| 280 | 1244.22 | 1250.03 | 1255.84 | 1261.56 | 1267.29 | 1272.91 | 1278.63 |
| 300 | 1241.72 | 1247.61 | 1253.51 | 1259.31 | 1265.12 | 1270.85 | 1276.58 |

| Pressure lb. per sq. in. | 1050 | 1100 | 1150 | 1200 |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
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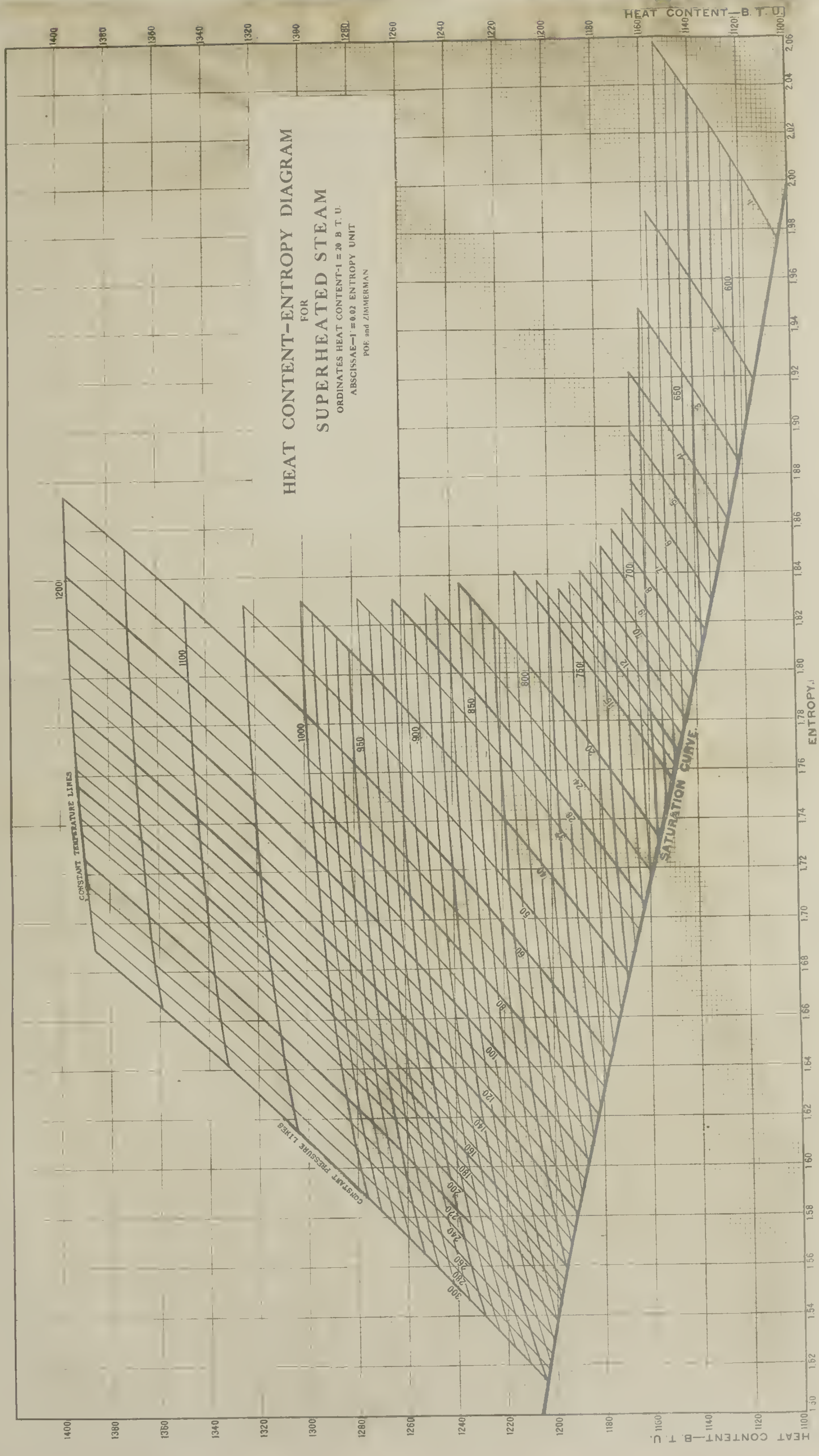
| 15 | | | | |
| 20 | | | | |
| 24 | | | | |
| 28 | | | | |
| 32 | | | | |
| 40 | | | | |
| 50 | 1324.55 | 1349.04 | | |
| 60 | 1323.82 | 1348.41 | 1373.17 | 1398.09 |
| 70 | 1323.08 | 1347.78 | 1372.63 | 1397.62 |
| 80 | 1322.34 | 1347.16 | 1372.09 | 1397.16 |
| 90 | 1321.60 | 1346.52 | 1371.55 | 1396.69 |
| 100 | 1320.85 | 1345.88 | 1370.88 | 1396.21 |
| 110 | 1320.06 | 1345.24 | 1370.45 | 1395.74 |
| 120 | 1319.34 | 1344.58 | 1369.92 | 1395.26 |
| 130 | 1318.57 | 1343.93 | 1369.35 | 1394.78 |
| 140 | 1317.80 | 1343.27 | 1368.78 | 1394.29 |
| 150 | 1317.03 | 1342.61 | 1368.20 | 1393.80 |
| 160 | 1316.25 | 1341.94 | 1367.62 | 1393.31 |
| 170 | 1315.28 | 1341.27 | 1367.04 | 1392.82 |
| 180 | 1314.47 | 1340.60 | 1366.46 | 1392.32 |
| 190 | 1313.66 | 1339.92 | 1365.87 | 1391.82 |
| 200 | 1312.84 | 1339.24 | 1365.22 | 1391.31 |
| 220 | 1311.19 | 1337.86 | 1364.08 | 1390.30 |
| 240 | 1309.51 | 1336.46 | 1363.36 | 1389.27 |
| 260 | 1307.82 | 1335.05 | 1361.63 | 1388.22 |
| 280 | 1306.12 | 1333.62 | 1360.39 | 1387.17 |
| 300 | 1304.37 | 1332.17 | 1359.14 | 1386.11 |


HEAT CONTENT-ENTROPY DIAGRAM
FOR
SUPERHEATED STEAM
ORDINATES HEAT CONTENT-1 = 20 B. T. U.
ABSCISSAE-1 = 0.02 ENTROPY UNIT
POE and ZIMMERMAN
HEAT CONTENT—B. T. U.
ENTROPY
SATURATION CURVE
CONSTANT TEMPERATURE LINES
CONSTANT PRESSURE LINES